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FOURTH SERIES, BULLETIN 40

Clarion Clay of Hope and Lincoln Furnace Fields

By

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WILBER STOUT, *State Geologist*

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INTRODUCTION

The Clarion clay of Vinton County constitutes one of our most valuable assets in argillaceous materials of a high refractory quality. The object of this paper is to provide data regarding the nature of the material and to promote its development in a large way. In preparing this report the author drew freely on an original paper, "Clarion Clay of Vinton County, Ohio," published in the Journal of the American Ceramic Society, Volume 15, No. 7, July, 1932. Permission was granted for use of the paper by the American Ceramic Society, April 4, 1940. Data from Bulletins Nos. 26 and 31, Geological Survey of Ohio, are also included. Further, the work was modified and enlarged by new material, sections measured and analyses made in 1939.

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CHAPTER I

REGIONAL DISTRIBUTION OF MEMBER

The term Clarion was applied geologically in 1858 by H. D. Rogers of the Pennsylvania Geological Survey to a stratum of coal that outcropped prominently along the Clarion River of that State and occupied a position about midway in the interval between the Brookville and the Lower Kittanning coals.[1] As many coal members somewhere bear well developed under clays of value or prominence, the convenient designation for the clay became that of the overlying coal; hence the name Clarion clay. This horizon in Pennsylvania is attributed to yield the great deposits of superior quality clay of the Clearfield District, which is by far the most important source for high grade refractory ware in the United States. In this field the deposits contain plastic clay, several varieties of hard flint clay, and locally high aluminous burly and diaspore clays.

In Maryland the Clarion clay of the Mount Savage District has been utilized for heat resisting ware since 1841. Here the deposits yield a flint clay, hard and refractory, and a plastic clay, both physically and chemically of excellent quality.

The Clarion member appears again on the west flank of the Appalachian Geosyncline in the Panhandle of West Virginia in Brooke and Hancock counties and along the river front in Ohio in Jefferson and Columbiana counties. In the West Virginia area the member is a plastic clay of a siliceous nature and of moderate heat resisting quality. It has been worked for many years to some extent for building brick, ladle brick, fireproofing, etc.

In eastern Ohio in northern Jefferson and southern Columbiana counties the Clarion clay is well developed and quite persistent. In this field the deposits are usually plastic clay somewhat siliceous in composition but in local areas they are large lenses of plastic clay high in alumina and irregular masses of flint clay of excellent quality. Such clays have been utilized for about 100 years for stoneware, yellow ware, fire brick, building brick, sewer pipe, fireproofing, and terra cotta.

[1]Rogers, H. D., First Geological Survey of Pennsylvania, Vol. II, pp. 475-490, 1858.

Throughout central Ohio from Columbiana to Perry County the member is absent save for small and widely scattered deposits of little ceramic value. It appears with fair thickness and properties in local areas in Perry and Hocking counties. In Ohio the main fields for both coal and clay are in the southern part of the State in Vinton, Jackson, and Lawrence counties. In general, the associated coal is of mineable thickness and thus becomes an adjunct of value. In Lawrence County this clay is widely distributed but is usually siliceous in quality. Locally, however, lenses of flint clay appear on the horizon. The stratum varies from 1 to 12 feet in thickness and in the better fields ranges from 6 to 10 feet. These clays have been employed for fire brick, building brick, and quarry tile. In southern Jackson County the Clarion clay is seldom more than 5 feet in thickness and is decidedly siliceous in composition. In the northern part of the area in a small field near Lincoln Furnace in northern Milton Township, the member measures from 6 to 12 feet in thickness and changes to a high aluminous plastic clay with excellent refractory properties.

In Ohio the Clarion clay is at its best both as to quantity and as to quality in Vinton County. The largest field centers around Hope Furnace in Brown Township. The area next in importance lies north of Lincoln Furnace in southeastern Clinton Township and east of this old stack in southwestern Vinton Township. Small outlying deposits of good clay also appear west of McArthur in western Elk, eastern Richland, southeastern Jackson, and southwestern Swan townships.

CHAPTER II

HOPE FURNACE FIELD

LIMITS OF FIELD

The Hope Furnace field includes nearly all of Brown Township with small adjacent areas. In this locality the Clarion clay is very persistent in extent, regular in structure, uniform in composition, and definite in thickness. In Brown Township the only exceptions are in the western tier of sections where some wants, thin clay, and tracts with mined out coal are present. The total area of Clarion clay in Brown Township is close to 29 square miles. Of this not less than 25 square miles is potentially productive. The main part of the field lies on Sandy Run and its tributaries, along Raccoon Creek in the southern part of the township, and on Two Mile Run in the northern part. Throughout this extent the member maintains the high standard necessary for successful industrial development.

The Hope Furnace field may also be increased considerably by additions in adjacent areas. The member is locally well represented in the northeastern part of Madison Township but is much impoverished, often less than a foot of sandy clay, south of Zaleski along Raccoon and Wheelabout creeks. The development and continuity of the stratum where it disappears below drainage near Moonville on Raccoon Creek and northeast of Hope Furnace on Sandy Run indicate an extension of good clay on eastward into Waterloo Township, Athens County. To the north in Starr Township, Hocking County, the Clarion member is generally present but it is thinner and more patchy in distribution and in general is less reliable in quality. These additions increase the area of the main Hope Furnace field by several square miles, thus making it of sufficient size to support many factories.

In the Hope Furnace field in Brown Township the Clarion clay seldom measures less than 5 feet in thickness and in places expands to as much as 12 feet. The average measurement from many sections scattered throughout the area is close to 7 feet.

KINDS OF CLAY

Normally the member is composed of three rather distinct varieties of clay, differing considerably in their physical and chemi-

cal properties. The basal portion of the bed is a plastic clay light in color and definitely siliceous in composition. It changes from a slightly siliceous clay to a clay-bonded sandstone. In this part mica is a common constituent. Other damaging impurities, such as ferruginous matter in shot and concretions, pyrite in grains and scales, and gypsum in crystals, are rather commonly present but, at most, in minor quantities. In general the clay in the lower part of the bed is a good clean moderately siliceous material, useful for many ceramic purposes. The mean thickness of this part of the member is 3 feet 3 inches. The variations, however, are from 1 foot 6 inches to 4 feet 4 inches.

The middle portion of the Clarion member is a high aluminous plastic material, commonly referred to by the miners as "cream" clay. In plasticity and weathering it really belongs about midway between a plastic clay like the Lower Kittanning and a true semi-flint clay such as that of the Sciotoville member. In some places it changes sufficiently to be called with propriety a semi-flint. On weathering it first breaks down into a grainy mass and then with long exposure it passes to its ultimate particles. The bonding power of this clay is thus somewhat limited but is sufficient and, in fact, is about right for ease in working through the various machines employed in the ceramic industry. This part of the Clarion clay is normally light to bluish gray in color but locally it is somewhat darkened by carbonaceous pigments. On weathering the material assumes light cream or buff tints. This clay is smooth to the touch and fine in texture. The chief mineral components were all so reduced by the physical and chemical processes during sedimentation that none is discernible to the eye. The cream clay is regularly and prominently slickensided but the markings are not closely spaced. The content of mica, pyrite, free silica, gypsum, and limonite is uniformly too low to be damaging in effect. The mean thickness of the cream clay in the Hope Furnace field in Brown Township is 3 feet 4 inches and its variation from 1 foot 10 inches to 7 feet 2 inches. On the whole it is a high grade material.

In most of the Hope Furnace field the clay in the upper part of the Clarion member is physically different from that in either the middle or lower part. In its common properties it tends toward the flint clay type and in a strict classification may be called a soft flint clay. It appears to have the composition and the fineness of grain of the true flint clays but not the density or set of particles. This clay breaks with a limited conchoidal fracture, has only scat-

tered imperfect slickensides, and, on exposure to the elements, slakes with an angular fracture. When finely ground and kneaded with water it develops a limited plasticity, about on a par with that produced with true semi-flint clay. It is fine in grain and smooth to the touch. The flinty clay in the upper part of the Clarion member is usually distinct from the plastic below in that it is more highly colored, the shade being from dark gray to nearly black. The predominating pigment, although small in quantity, is highly diffused carbonaceous or coaly matter. This clay is low in impurities except for that below the overlying coal, which locally contains some pyrite distributed along root impressions in thin sheets or nodules. The usual range in thickness is from 4 inches to 1 foot 6 inches and the mean measurement close to 9 inches. It is a refractory clay fitted for high heat duty service.

CONDITIONS FOR MINING

As the winning of the Clarion clay in the Hope Furnace field must be largely through drift mining, the question of roof is important. The clay stratum is immediately overlain by the Clarion coal which, with few exceptions, is without weak partings but through jointing is of the blocky type. From many sections throughout the field the thickness of the coal bed varies from 1 inch to 2 feet 3 inches and measures on the average 1 foot 1 inch. The coal forms a good roof as the stratum is not easily broken and as it prevents the air from "cutting" or spalling the overlying shales. Another important feature of the roof is the character and thickness of the shale which lies above the coal and which forms the real support for drift mining. This shale is carbonaceous in composition, somewhat platy and fissile in nature, quite resistant to weathering, and possesses a high breaking strength. The average thickness of carbonaceous shale is close to 5 feet and its continuity is such that it extends over the entire field. The lower part of this shale, about 1 foot 6 inches, is of a canneloid nature and somewhat blocky in structure. These shales are locally overlain by the Scrubgrass coal, usually thin and shaly in character. Above this impure coal the normal deposits are either sandstones or siliceous shales. The roof of the Clarion clay in the Hope Furnace field is thus strong and safe and should allow a high yield of clay.

DIP OF THE STRATUM

Near New Plymouth in the northwestern corner of Brown Township the Clarion clay lies at an elevation of approximately 880

feet, which is well up on the hills more than 120 feet above the valley floors. On Twomile Run the member passes under covering in the southeastern part of Section 24. At this place the position of the clay is close to 800 feet above tide. In the southwestern corner of Brown Township, in Section 31, the elevation of the stratum is about 835 feet. The dip of the bed eastward along Raccoon Creek is such that the member finally disappears below the flood plains near Moonville in the central part of Section 7. In this vicinity the deposits lie near the 690 foot contour. In a northwest-southeast direction across the field, or from New Plymouth to Moonville, the Clarion member descends from 900 to 690 feet in elevation, thus giving it an average dip of 29.3 feet per mile. The structural features in Brown Township are relatively small. A low structure extends from New Plymouth southeastward to Ingham and another from Section 33 southeastward to Moonville. Between these structures is a rather narrow but sharp syncline. Another, less prominent, extends across the northeastern corner of the township. The general dip in the area is to the east and to the south, the former being more than twice the latter. For economy in haulage and for ease in drainage, drift mines in the Hope Furnace field should be planned to take advantage of the natural slope of the stratum.

SPECIAL GEOLOGIC FEATURES

The geologic features of the Clarion clay in the Hope Furnace field are somewhat abnormal when compared with the relationships found farther south in Jackson, Gallia, Scioto, and Lawrence counties. The differences include changes in the thickness and in the structure of the associated Clarion coal, the appearance in Vinton County of the Scrubgrass coal with several feet of carbonaceous shale, the expansion northward of the Clarion-Vanport and of the Clarion-Lower Kittanning intervals, and the absence in Brown Township of the Vanport limestone, its place being taken by sandstone. In the Hope Furnace field the Clarion clay lies on the average about 54 feet below the Lower Kittanning coal, more than 88 feet below the well developed Middle Kittanning coal, and nearly 57 feet above the Brookville coal with its associated fossiliferous Putnam Hill limestone. In general, the succession of strata and the intervals of separation are fairly uniform.

The changes of most importance economically are those which take place laterally within the clay bed. In a short distance along the borders of the field the stratum may be altered from a thick deposit of excellent clay to a thin layer of very siliceous and worth-

less material. On account of such rapid transitions careful prospecting is necessary to clearly define the productive areas. Within the basin, however, the clay is steady in distribution and uniform in thickness and in quality. The geological features are well shown in the detailed study of the field that follows.

DETAILED GEOLOGY OF THE HOPE FURNACE FIELD

South of Zaleski along Wheelabout Creek in Madison Township the Clarion clay is thin and siliceous, its place being taken by sandstone. The overlying coal, however, is well developed and is mined in many places. West of Zaleski in Elk Township the clay is poor in quality and reduced in thickness. Northeast of Zaleski in Section 30, Madison Township, the clay assumes about normal thickness and average quality. A section taken along an old road in the southwestern part of Section 30, Madison Township, shows the geology of the member exceptionally well. The measurements follow:[1]

SECTION No. 286

Allegheny formation	Ft.	In.
Top of hill	..	..
Covered	2	0
Horizon of **Upper Freeport** coal	..	..
Clay, light to pink, much weathered	5	0
Shale with nodules of calcareous and ferruginous materials, horizon of **Upper Freeport** limestone	2	0
Shale, yellow, parts covered	13	0
Clay, poorly exposed, **Bolivar**	2	0
Shale and covered	15	0
Shale and shaly sandstone, parts covered	22	0
Clay with poorly exposed nodules of iron ore and limestone, **Lower Freeport** limestone horizon	6	0
Shale, gray, argillaceous	5	0
Sandstone, massive, soft	36	0
Covered	8	0
Coal blossom, **Middle Kittanning**	1	0
Clay, light, plastic	1	0
Shale, siliceous	16	0
Clay, light, impure, **Oak Hill**	3	0
Shale, gray, siliceous	16	0
Coal, weathered, **Lower Kittanning**	2	0
Clay, light, plastic	7	0
Sandstone, massive, soft	34	0
Shale, gray, siliceous	6	0
Shale, gray, and covered	5	0
Shale, dark, carbonaceous	5	0
Covered	11	0

[1]Geol. Survey Ohio, 4th Ser., Bull. 31, pp. 336-7, 1927.

		Ft.	In.
Shale, black		2	7
Coal blossom, **Clarion**		2	0
Clay, plastic, dark	**Clarion**	3	5
Clay, plastic, light, siliceous	**Clarion**	3	0
Sandstone, shaly, argillaceous		..	4
Sandstone, shaly, ferruginous		..	4
Shale, gray		3	0
Ore, kidney		..	2
Shale, gray		12	8
Shale, bluish gray		4	8
Shale, gray, very fossiliferous, **Putnam Hill**		1	9
Coal, good	**Brookville**	1	0
Coal, bony	**Brookville**	..	6
Pottsville formation			
Clay, light, plastic		2	6
Shale, gray		6	3
Shale, dark, **Tionesta** coal horizon		..	4
Clay, light, plastic		1	8

In the above section the position of the Clarion clay (top) is thus 72 feet 7 inches below the Lower Kittanning coal, 110 feet 7 inches below the Middle Kittanning coal, both intervals above normal, and 30 feet 10 inches above the Brookville coal, this interval about normal. At this place the Clarion clay is of fair quality.

North of Zaleski in sections 31 and 25, Brown Township, the Clarion clay is generally thin and siliceous. Further, the associated Clarion coal has been largely removed by mining, which condition causes complications and losses in the winning of the clay by drifting. In Section 19 the Clarion clay assumes its full measurement and quality but the overlying coal shows a decided contraction in thickness. At the Brewer Cut of the Baltimore and Ohio Railroad the following measurements were obtained.

SECTION No. 274

		Ft.	In.
Shale, gray		10	0
Coal, bony, **Scrubgrass**		1	3
Shale, dark, fissile		6	0
Coal, good	**Clarion**	1	8
Shale, argillaceous	**Clarion**	..	1
Coal, good	**Clarion**	..	7
Clay, dark, flinty, good	**Clarion**	1	0
Clay, plastic, light, excellent	**Clarion**	2	9
Clay, plastic, light, siliceous	**Clarion**	2	6
Shale and shaly sandstone		5	10
Ore, siliceous, in two layers		..	8
Shale and shaly sandstone		5	6
Ore, nodular, irregular		..	1
Coal, bony, **Winters**		..	7

	Ft.	In.
Clay, siliceous, plastic, light	6	0
Shale, gray, siliceous	10	0
Level of railroad	..	..

At this place the top of the Clarion clay lies about 92 feet below the Middle Kittanning coal and 51 feet above the Brookville coal, which is found at water level on Raccoon Creek. The associated Clarion coal, although rather high in sulphur and ash, is of fair quality for steaming purposes and may be mined conveniently in conjunction with the clay. The overlying carbonaceous shale forms a good roof for drift mining and will thus allow a high recovery of both clay and coal. At the Brewer Cut the base of the Clarion clay is about 29 feet above the level of the railroad, which is a convenient height for a tipple.

In the deep hollow in the south central part of Section 19, south of Raccoon Creek, more than 5 feet of Clarion clay of excellent quality was exposed in the stream bed at an elevation of approximately 740 feet. The member appears just above drainage level on the Ira Penny farm in east central Section 19. The deposits show the following specific features:

SECTIONS No. 319 and 685a

		Ft.	In.
Sandstone, massive, soft		34	0
Shale, carbonaceous, soft		..	6
Coal, weathered, **Middle Kittanning**		2	6
Shale and covered		33	0
Coal blossom, **Lower Kittanning**		1	0
Clay and covered		5	0
Covered		5	0
Sandstone and covered		31	4
Shale and covered		9	0
Coal, bony, **Scrubgrass**		1	4
Shale, black, fissile		6	10
Coal, good, **Clarion**		1	5
Clay, dark, flinty	**Clarion**	1	2
Clay, light, plastic, excellent		3	6
Clay, plastic, bluish-gray, siliceous		1	8
Sandstone, light, clay-bonded		..	1
Coal, shaly		..	½
Clay, dark, plastic, good		..	4½
Coal, shaly		..	½
Clay, light, plastic		..	6
Coal, shaly		..	1
Clay, plastic, not well exposed		1	0
Stream bed		..	..

As the Clarion clay at this place is at drainage level its extent to the south is not known but from the general features the field

will extend at least a mile or more to the south. The locality will thus afford a large volume of high grade clay, a sufficient reserve for any plant. Where naturally exposed the clay is of excellent quality as most of it is of the high aluminous type. Here also the Clarion and Middle Kittanning coals are adjuncts of value.

Along Raccoon Creek in central Section 7, just below the old site of Coe's Mill, on land of A. E. Kennard, the Clarion clay outcrops about 10 feet above water level. The deposit was sampled for testing in May, 1925, by Wilber Stout assisted by Miles Ogan. The strata exposed at this place are given below:

SECTIONS No. 553 and 693

		Ft.	In.
Shale, dark		5	0
Coal, bony, **Scrubgrass**		..	8
Shale, black, carbonaceous, fissile		6	1
Coal, blocky, **Clarion**		1	1
Clay, dark, flinty, sampled		..	6
Clay, light, plastic, very pure, sampled		2	8
Clay, light, plastic, very siliceous, sampled	**Clarion**	1	4
Clay, light, plastic, siliceous, sampled		1	3
Clay, light, plastic, very siliceous, sampled		..	11
Sandstone, argillaceous		..	6
Shale and covered		7	0
Water level, Raccoon Creek, 680 elevation		..	..

The deposit contains no apparent impurities such as sandstone layers, ferruginous concretions, pyrite masses, or gypsum crystals. As is commonly the case, the lower part of the stratum is siliceous and slightly micaceous in character. The general properties of the Clarion clay on the A. E. Kennard land are shown in the following tests. The sample represents 6 feet 8 inches of strata.[1] Analyst, Downs Schaaf.

Chemical analysis

Loss at 105° C	1.32
Ignition loss	8.69
Silica, SiO_2	55.90
Alumina, Al_2O_3	28.05
Ferric oxide, Fe_2O_3	1.87
Calcium oxide, CaO	trace
Magnesium oxide, MgO	0.53
Titanic oxide, TiO_2	1.72
Phosphorus pentoxide, P_2O_5	0.02
Sodium oxide, Na_2O	0.55
Potassium oxide, K_2O	1.62
Sulphur, S	0.017
Total carbon, C	0.26
Inorganic carbon, C	0.06

Percentage oxide ratio

K_2O	.058			SiO_2	1.993
Na_2O	.019			TiO_2	.061
CaO	.000	Al_2O_3	1.00	P_2O_5	.001
MgO	.019				
FeO	.067				
RO	.163				

[1]Geol. Survey Ohio, 4th Ser., Bull. 31, pp. 216-7, 1927.

Physical tests, by Orton Ceramic Laboratory

Working properties: The plastic properties of this clay are such that it works well in the machine.

Drying behavior: It dries satisfactorily in any type of drier.
Drying linear shrinkage: 3.5 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	1.5	16.0	Pink buff
Cone 04	3.7	11.8	Pink buff
Cone 02	4.2	11.4	Pink buff
Cone 1	4.6	10.5	Pink buff
Cone 3	4.9	9.5	Buff
Cone 5	5.1	8.8	Buff
Cone 7	5.8	6.5	Buff
Cone 9	6.5	3.2	Gray buff
Cone 11	6.3	3.3	Gray buff

Overburning temperature: Above cone 11 (above 1,350° C or 2,462° F.)

Best apparent burning range: Cones 3 to 11 (1,190 to 1,350° C. or 2,174 to 2,462° F.) It is steel hard at cone 3.

Total linear shrinkage at cone 7: 10 per cent.

Deformation temperature: Slightly below cone 29 (slightly below 1,650° C. or 3,002° F.)

Possibilities: Intermediate heat duty refractory ware, face brick, sewer pipe, fireproofing, and terra cotta.

The Clarion clay disappears below the waters of Raccoon Creek near the eastern boundary of Section 12, Knox Township. The clay, a few feet in thickness but poorly exposed, is of good quality, indicating a normal condition of the stratum. East of Moonville the member is also under cover along Hewett Fork in Waterloo Township, Athens County, but is within easy reach of shafting. Its position below the flood plain is approximately 35 feet at Ingham and 60 feet at Mineral. The thickness and quality of the Clarion clay, however, have not been determined east of Moonville in Waterloo Township, Athens County, or south of this place along Raccoon Creek in Knox Township, Vinton County.

Along Raccoon Creek in the southwestern part of Section 8, Brown Township, the Clarion clay is well exposed in the cut of the Baltimore and Ohio Railroad. Its position is just above track level and from appearance has excellent quality. The measurements obtained at this place are given below:

SECTION No. 271

		Ft.	In.
Sandstone, massive		10	0
Shale, gray		....	8
Coal, **Lower Kittanning**		1	8
Clay, light, plastic, siliceous, **Lower Kittanning**		3	0
Sandstone, variable, upper part argillaceous		8	0
Clay, plastic, irregular		2	0
Sandstone, massive, soft		34	0
Disconformity (**Scrubgrass** coal replaced)		....	..
Shale, dark, carbonaceous		1	9
Ore, irregular		..	10
Shale, black, fissile, sparingly fossiliferous		3	2
Coal, blocky, **Clarion**		..	11
Clay, dark, flinty, good	**Clarion**	1	0
Clay, light, plastic, excellent	**Clarion**	4	6
Covered			

The Clarion clay exposed in this cut is of high purity and rank, approaching a semi-flint in some of its physical properties. It weathers into a grainy mass with only a moderate amount of plasticity. Nearby about 2 feet of siliceous plastic clay forms the basal portion of the deposit. In this locality only drift mining may be practiced as the hills are steep owing to the presence of massive resisting sandstone above the Clarion, Lower Kittanning, and Middle Kittanning coals. As shown in the above section, the overlying strata are favorable for this method of recovery. The position of the bed is about 720 feet above tide or 30 feet above the level of Raccoon Creek.

On the north bank of the small stream in the deep hollow, about one-fifth mile north of Raccoon Creek, in the west central part of Section 8, Brown Township, on land of the Ohio Oil Company, the Clarion clay is well exposed through erosion. The measurements secured are given below:

SECTION No. 487

		Ft.	In.
Sandstone, massive		10	0
Shale, gray, siliceous		7	0
Shale, dark, carbonaceous		..	9
Coal, blocky, hard, **Clarion**		..	11
Clay, dark, flinty		..	4
Clay, light, plastic, excellent	**Clarion**	1	10
Clay, light, plastic, siliceous	**Clarion**	4	4
Clay, light, plastic, very siliceous	**Clarion**	2	2
Shale, blue, fine-grained		1	0
Stream bed		..	..

At this exposure the dark flinty clay and the high aluminous plastic give way in part to the more siliceous material. The total thickness of the member, however, is about normal. The deposit lies close to 720 feet above tide and at drainage level. Its position here is about 90 feet below the Middle Kittanning coal, which contains 2 feet 6 inches of clean fuel, exclusive of partings, and has a massive sandstone for the roof.

The continuity of the Clarion member is shown by exposures along the Raccoon Valley to the west of the above locality. On the Timothy Clifford property just south of Raccoon Creek, in the southeastern part of Section 14, the stratigraphic features are as follows:

SECTIONS 420 and 419 COMBINED

		Ft.	In.
Sandstone, massive		45	0
Clay and bony coal		..	3
Coal, good		1	11
Clay, impure	**Middle Kittanning**	..	1
Coal, good		..	5
Covered		7	4
Clay, plastic, **Oak Hill**		7	0
Covered		15	0
Sandstone, massive		53	0
Coal, shaly, **Scrubgrass**		..	1
Clay shale		2	7
Ore, blackband, shaly, weathered		2	6
Shale, gray		..	8
Shale, black, bony		..	3
Coal, blocky, hard, **Clarion**		1	1
Clay, dark, flinty, good		..	8
Clay, light, plastic, excellent	**Clarion**	3	10
Clay, light, plastic, siliceous		1	8
Sandstone, light, very argillaceous		3	8

Here the exposure shows an exceptional thickness of the high aluminous cream clay. One of the few plant sites along the Raccoon Valley in the Hope Furnace field is on the Clifford property north of the Baltimore and Ohio Railroad. It is above flood stage and has advantages for a clay supply. The method of mining, however, is nearly entirely through drifting.

South of Hope Station on the property of Jesse White the Clarion clay has excellent development where exposed in a ravine near his house. A sample was taken for testing by Wilber Stout

assisted by Miles Ogan in 1923. The measurements of the various strata laid bare here are given below:

SECTIONS No. 391 and 537

		Ft.	In.
Shale and sandstone		10	0
Sandstone, massive		11	0
Covered		10	5
Shale, dark, hard, carbonaceous		5	0
Coal, weathered, **Clarion**		1	0
Clay, flinty, dark, sampled		1	0
Clay, plastic, light, very pure, sampled		3	6
Clay, plastic, light, slightly siliceous, sampled		2	6
Clay, plastic, dark gray, pure, sampled	**Clarion**	1	4
Clay, plastic, light, very siliceous, rejected		8	8
Sandstone, light, clay bonded		2	0
Covered.			

The sample as tested included all the clay in the 8 feet 4 inches section. The chemical work was done by Downs Schaaf and the physical testing at the Orton Ceramic laboratory. The results follow:[1]

Chemical analysis

Loss at 105° C	0.92
Ignition loss	8.73
Silica, SiO_2	54.29
Alumina, Al_2O_3	29.37
Ferric oxide, Fe_2O_3	1.98
Calcium oxide, CaO	0.08
Magnesium oxide, MgO	0.52
Titanic oxide, TiO_2	1.07
Phosphorus pentoxide, P_2O_5	0.05
Sodium oxide, Na_2O	0.66
Potassium oxide, K_2O	2.29
Sulphur, S	0.04
Total carbon, C	0.20
Inorganic carbon, C	0.00
True specific gravity	2.64

Percentage oxide ratio

K_2O	.078			SiO_2	1.848
Na_2O	.022			TiO_2	.036
CaO	.003	Al_2O_3	1.00	P_2O_5	.002
MgO	.018				
FeO	.061				
RO	.182				

Physical tests, by Orton Ceramic Laboratory

Working properties: The clay is plastic and smooth-textured. It machines well except for a few laminations which may be remedied by the addition of siliceous clay from the lower part of the deposit or of calcined clay or grog from the same material.

Drying behavior: This clay dries with perfect safety under any of the conditions ordinarily employed in drying such products.

Drying linear shrinkage—4.0 per cent.

[1]Geol. Survey Ohio, 4th Ser., Bull. 31, pp. 211-2, 1927.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	2.8	16.25	Light buff
Cone 04	4.8	10.50	Light buff
Cone 02	5.5	7.90	Light buff
Cone 1	6.2	6.08	Medium buff
Cone 3	6.4	6.04	Medium buff
Cone 5	7.0	5.72	Medium buff
Cone 7	7.0	2.65	Light gray buff
Cone 9	7.2	2.58	Light gray buff
Cone 11	7.4	2.60	Gray buff

Overburning temperature: Above cone 11 (above 1,350° C. or 2,462° F.)

Best apparent burning range: Cone 02 to above 11 (1,110 to above 1,350° C. or 2,030 to above 2,462° F.)

Total linear shrinkage at cone 7: 11.0 per cent.

Deformation temperature: Slightly less than cone 31 (1,685° C. or 3,065° F.)

Possibilities: Intermediate heat duty refractory ware, face brick, hollow block, fire proofing, sewer pipe, and terra cotta. It has a long burning range and develops a good clear color.

Both the chemical analysis and the physical tests show this to be far above the average for a coal formation clay of the plastic type. Its range of usefulness is wide. Within its field it will give a high yield of first grade ware. The deposit is situated favorably for development. The elevation of the member at this place is close to 740 feet, which is about 50 feet above the valley floor. Exposures on the Betz and Dunn properties to the west also indicate that the Clarion clay maintains excellent continuity, thickness, and quality. The area also affords another plant site. The advantages here are sufficient room for large works, freedom from flooding, abundance of high grade clay, availability of fuel supply from local coals, proximity of clay to works, and conditions favorable for drift mining.

On the same property in a strip mine samples of the three distinct divisions of the Clarion clay were taken to determine their chemical composition. The samples were taken by channeling by Wilber Stout, September 13, 1939. The section of the mine operated by Hope Fire Clay Company follows:

	Ft.	In.
Sandstone, massive	10	0
Coal, impure, **Scrubgrass**	....	8½
Shale, black, fissile, carbonaceous	3	9
Coal, blocky, **Clarion**	1	3

	Ft.	In.
Clay, flinty, dark to dark gray, irregular in thickness, sampled	2	0
Clay, plastic, cream, light, some slickensides, smooth feel, sampled	2	6
Clay, light, very siliceous, plastic	1	4
Clay, plastic, slightly siliceous, light, smooth, sample of 2 feet 11 in.	1	7
Clay, very siliceous, not sampled	....	..

The chemical analyses of these three divisions of the Clarion clay are given below. Analyst, Downs Schaaf.

	Top 2 ft.	Middle 2 ft. 6 in.	Bottom 2 ft. 11 in.
Silica, SiO_2	49.72	44.93	63.22
Alumina, Al_2O_3	30.25	33.80	23.25
Ferric oxide, Fe_2O_3**	1.68	1.40	0.20
Pyrite, FeS_2	0.42	0.57	1.01
Magnesium oxide, MgO	0.45	0.68	0.61
Calcium oxide, CaO	0.18	0.12	0.14
Sodium oxide, Na_2O	0.15	0.18	0.28
Potassium oxide, K_2O	1.08	1.15	3.04
Water, hydroscopic, H_2O-	1.79	3.02	1.01
Water, combined, H_2O+	10.50	11.40	5.72
Carbon dioxide, CO_2	0.38	0.36	0.20
Titanic oxide, TiO_2	2.70	2.12	1.01
Zirconium oxide, ZrO_2	<0.01	<0.01	<0.01
Vanadium oxide, V_2O_3	<0.01	<0.01	<0.01
Phosphorus pentoxide, P_2O_5	0.05	0.10	0.07
Sulphur trioxide, SO_3	0.01	0.02	<0.01
Manganous oxide, MnO	0.04	0.04	0.04
Carbon, organic, C	0.60	0.20	0.20
Hydrogen, organic, H	0.04	0.02	0.02
Total	100.04		

**All Fe, other than that allocated to FeS_2, is calculated to Fe_2O_3 since there is too much carbonaceous matter for an accurate FeO determination.

At Hope Station the Clarion clay is regularly mined by the Hope Clay Company of McArthur. The section follows:

SECTION No. 700

	Ft.	In.
Shale, black, carbonaceous, somewhat fissile	5	0
Coal, blocky, hard, **Clarion**	1	4
Clay, flinty, dark, good	1	3
Clay, plastic, light, excellent	3	0
Clay, plastic, light, siliceous	4	0
Sandstone, light, clay-bonded	..	..

A sample was taken in 1936 of the 3 feet of high grade plastic clay for thesis work by J. O. Everhart.[1] Analyst, Downs Schaaf.

Silica, SiO_2	46.72
Alumina, Al_2O_3	33.06
Ferric oxide, Fe_2O_3	0.68

[1]Everhart, J. O., Secondary Expansion in Refractory Clays. Engineering Experiment Station, Ohio State University, Vol. VII, No. 1, p. 5, May, 1938.

Ferrous oxide, FeO	0.55
Pyrite, FeS_2	0.34
Magnesium oxide, MgO	0.19
Calcium oxide, CaO	0.61
Sodium oxide, Na_2O	0.42
Potassium oxide, K_2O	1.53
Water, hydroscopic, H_2O-	2.21
Water, combined, H_2O+	11.50
Carbon dioxide, CO_2	0.02
Titanic oxide, TiO_2	2.20
Phosphorus pentoxide, P_2O_5	0.12
Sulphur trioxide, SO_3	0.01
Manganous oxide, MnO	0.01
Zirconium oxide, ZrO_2	0.01
Carbon, organic, C	0.04

In this mine the flint clay varies from 8 inches to 2 feet or more but averages close to 1 foot 3 inches. The thicker bodies are only lenses, local in area. In kind this clay should be classed as a soft flint. It slakes with a grainy fracture, develops little bonding strength on working, has high heat resisting properties, and has the chemical components shown in mature reduction.

The upper division of the plastic clay or the "cream" part expands from 1 foot 6 inches to 4 feet 6 inches in thickness. The usual measurement, however, is not far from 3 feet. This clay maintains high purity and uniformity throughout the mine. It is well slickensided, light in color, and smooth to the touch. In bonding properties it should be classed as a short plastic clay.

The siliceous clay, or basal portion of the deposit, is fine in texture, has slightly more plasticity than the "cream" clay, and, aside from free silica, contains little detrimental matter. In fact it is a good siliceous clay useful for many purposes. This part of the member varies from 2 to 6 feet in thickness but commonly measures from 3 to 4 feet.

The associated Clarion coal with the overlying black shale forms a satisfactory roof for drift mining. It is safe and allows a good yield of clay. The clay-bonded sandstone forms a good floor for timbering and is moderately free from rolls and dips.

Along the cut of the road just east of Hope Dam the Clarion clay was well exposed for observation. At this place samples were taken of the flint, cream, and siliceous clay by Wilber Stout, September 12, 1939. The section follows:

	Ft.	In.
Shale, dark, carbonaceous	5	0
Coal, blocky, **Clarion**	1	6
Clay, flinty, dark, good, sampled	1	2

	Ft.	In.
Clay, cream, plastic, light gray, some slickensides, sampled	3	5
Clay, siliceous, plastic, light, sampled	3	1
Clay, very siliceous, light, not sampled	2	0
Shale, siliceous	1	0
Road level	..	..

The chemical components in these samples are given below. Analyst, Downs Schaaf.

	Flint clay	Cream clay	Siliceous clay
Silica, SiO_2	45.50	46.98	64.68
Alumina, Al_2O_3	31.06	32.40	21.60
Ferric oxide, Fe_2O_3	0.84	0.53	0.44
Ferrous oxide, FeO	.....*	.....*	0.34
Pyrite, FeS_2	0.34	0.59	0.28
Magnesium oxide, MgO	0.75	0.44	0.80
Calcium oxide, CaO	0.25	0.40	0.24
Sodium oxide, Na_2O	0.29	0.25	0.48
Potassium oxide, K_2O	1.47	1.48	2.61
Water, hydroscopic, H_2O—	4.53	3.20	1.15
Water, combined, H_2O+	10.88	10.50	5.70
Carbon dioxide, CO_2	0.40	0.30	0.22
Titanic oxide, TiO_2	1.60	2.40	1.35
Zirconium oxide, ZrO_2	<0.01	<0.01	<0.01
Vanadium oxide, V_2O_3	<0.01	<0.01	<0.01
Phosphorus pentoxide, P_2O_5	0.20	0.20	0.06
Sulphur trioxide, SO_3	0.34	0.03	0.03
Manganous oxide, MnO	0.03	0.03	0.03
Carbon, organic, C	1.34	0.27	0.07
Hydrogen, organic, H	.10	0.02	.....

*All iron, Fe, other than that allocated to pyrite, FeS_2, is calculated to ferric oxide, Fe_2O_3, since there is too much carbonaceous matter for an accurate ferrous oxide, FeO, determination.

The analyses of both the flint and cream clay show them to be very refractory, well able to withstand tests of Cone 31½ to Cone 32½. They are free from serious detrimental components for refractory ware. Their physical properties are excellent for either dry-press or stiff mud ware.

In a ravine west of Hope Dam and just above the embankment, the Clarion member was formerly well exposed in a prospect opening. The record as thus obtained is given below:

SECTION No. 312

	Ft.	In.
Shale, gray, siliceous	2	0
Coal and bone shale, much weathered, Scrubgrass	1	0
Shale, black, carbonaceous, platy	4	0

		Ft.	In.
Coal, blocky, good, **Clarion**		1	5
Clay, flinty, dark, good		1	6
Clay, plastic, light, excellent	**Clarion**	3	4
Clay, plastic, light, somewhat siliceous		3	8
Clay, plastic, light, very siliceous		2	0
Shale, argillaceous		2	0

At this place the elevation of the clay is approximately 740 feet above tide and its position nearly 50 feet above the flood plain of the stream. The clay is normal in character and in structure and maintains the high quality shown elsewhere in the field.

Few exposures, and these poor, were observed along the lower course of Little Sandy Run and in Sections 26 and 32. The evidence, however, indicates that in these areas the bed is generally thin and the clay siliceous. The member appears with more normal properties near the head of Little Sandy Run where its position is approximately 830 feet above tide. The following measurements were secured along the west bank of the stream in an eroded surface:

SECTION No. 309

		Ft.	In.
Shale, gray, argillaceous		3	0
Coal, bony, **Scrubgrass**		..	7
Shale, black, carbonaceous		3	1
Coal, blocky, good, **Clarion**		1	4
Clay, flinty, dark, good		..	4
Clay, plastic, light, excellent, lower part somewhat siliceous	**Clarion**	5	8
Sandstone, light, clay-bonded		1	0
Stream bed		..	..

The field of Clarion clay along Sandy Run and its tributaries in the central part of Brown Township is worthy of careful attention as the conditions are especially favorable for large ceramic operations. The clay has excellent continuity, uniformity, thickness, and purity, and occurs in such quantities as to sustain major works of large capacity. Mining conditions are excellent. The roof of the clay is everywhere the Clarion coal and a hard fissile shale, superimposed on which is a massive sandstone. Further, coal for manufacturing the clay into ware may be obtained from the Middle Kittanning member lying about 90 feet higher in the geological column, averaging slightly more than 3 feet of clean coal, having good conditions for drift mining, and extending unbroken except for valleys over a large area.

In Hope Hollow, one and one-fourth miles northwest of the old stack of Hope Furnace, the Clarion clay outcrops on the east

bank of the stream on land now controlled by U. S. Government but formerly owned by G. P. Drayer. The elevation of the bed here is close to 780 feet. The clay was sampled for testing in the regular way May 14, 1925, by Wilber Stout assisted by Miles Ogan and G. P. Drayer. The clay and related strata are shown in the following record:

SECTIONS Nos. 307 and 694

	Ft.	In.
Shale, black, carbonaceous	6	0
Coal, Clarion, absent	..	0
Clay, flinty, dark, sampled	..	10
Clay, plastic, light, excellent, sampled	4	6
Clay, plastic, light, somewhat siliceous, sampled	2	10
Sandstone, argillaceous, light	..	1
Clay, plastic, dark gray, somewhat siliceous	1	7
Clay, plastic, light, very siliceous	1	4
Sandstone, light, argillaceous	..	2
Shale and shaly sandstone	15	6
Stream bed	..	..

The sample used for testing was thus made up of the three parts or of 8 feet 2 inches of material. The analysis follows:[1] Analyst, Downs Schaaf.

Chemical analysis

Loss at 105° C	1.22
Ignition loss	8.02
Silica, SiO_2	56.89
Alumina, Al_2O_3	27.28
Ferric oxide, Fe_2O_3	1.75
Calcium oxide, CaO	trace
Magnesium oxide, MgO	0.62
Titanic oxide, TiO_2	1.52
Phosphorus pentoxide, P_2O_5	0.01
Sodium oxide, Na_2O	0.37
Potassium oxide, K_2O	2.45
Sulphur, S	0.006
Total carbon, C	0.17
Inorganic carbon, C	0.07

Percentage oxide ratio

K_2O	.090			SiO_2	2.085
Na_2O	.013				
CaO	.000	Al_2O_3	1.00	TiO_2	.056
MgO	.023				
FeO	.064			P_2O_5	.000
RO	.190				

Physical tests, by Orton Ceramic Laboratory

Working properties: The clay is plastic, smooth textured, and fine grained. It laminates but little in the machine.

Drying behavior: Ware made from this clay dries safely in any of the standard types of driers.

Drying linear shrinkage—4.0 per cent.

[1]Geol. Survey Ohio, 4th Ser., Bull. 31, pp. 214-5, 1927.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	1.5	16.2	Pink buff
Cone 04	3.5	11.9	Pink buff
Cone 02	4.3	11.0	Pink buff
Cone 1	4.8	9.6	Light buff
Cone 3	5.3	7.5	Light buff
Cone 5	5.8	7.2	Buff
Cone 7	6.3	5.0	Buff
Cone 9	6.8	2.9	Gray buff
Cone 11	7.1	2.8	Gray buff

Overburning temperature: Above cone 11 (above 1,350° C. or 2,462° F.).

Best apparent burning range: Cones 1 to 11 (1,150° C. to 1,350° C. or 2,102 to 2,462° F.). It is steel hard at cone 1.

Total linear shrinkage at cone 7: 10.3 per cent.

Deformation temperature: Slightly below cone 29 (slightly below 1,650° C. or 3,002° F.).

Possibilities: Intermediate heat duty refractory ware, face brick, sewer pipe, fireproofing, and terra cotta. The burning range is long and the color is a clear buff free from specks.

Along Sandy Run in the vicinity of Hope Furnace the Clarion clay lies close to the level of the flood plain. It disappears below drainage about one-fourth mile east of the old stack. The best exposure is at the base of the hill north of the stream and about one-eighth mile northwest of the furnace. A composite section at this place is given below:

SECTIONS Nos. 550 and 691A

		Ft.	In.
Sandstone, massive		43	0
Shale, dark		....	5
Coal, bony		....	5
Clay shale, carbonaceous		....	3
Coal, good	**Middle Kittanning**	2	4
Clay shale		....	1
Coal, good		....	5
Clay, siliceous, impure		3	6
Shale, gray, siliceous		19	8
Clay, dark, shaly		1	6
Coal smut and dark clay	**Oak Hill**	....	2
Clay, dark gray, impure		5	4
Clay, very ferruginous		1	0
Shale, gray		9	8
Coal, weathered, **Lower Kittanning**		1	5
Clay, plastic, light, fair quality	**Lower Kittanning**	3	6
Clay, plastic, light, siliceous		2	3
Sandstone, massive, soft, micaceous		53	6
Covered		2	0

		Ft.	In.
Shale, dark, carbonaceous		3	3
Coal, weathered, **Clarion**		1	2
Clay, flinty, dark, good		1	2
Clay, plastic, light, excellent	**Clarion**	7	2
Clay, plastic, light, very siliceous		1	6
Covered, level of flood plain		....	..

In the above section the stratigraphic relations of the Clarion member to others higher in the column are well shown. In this part of the field the Middle Kittanning coal has so thickened that it may be mined in a large way for a fuel supply. As shown by analyses, the quality of the coal is very satisfactory for ceramic work. Near Hope Furnace the Clarion clay lies about 730 feet above tide. At this exposure the member bears an exceptional thickness of "cream" clay which, however, may be only local in distribution. The area offers both clay and coal in large quantities.

Along the road about one-half mile south of Hope Furnace on land of U. S. Government, formerly owned by G. P. Drayer, the Clarion clay was sampled May 14, 1925, for testing by Wilber Stout assisted by Miles Ogan and G. P. Drayer. The clay was faced to a depth of 3 feet or more. About 130 pounds of material was taken from top to bottom of the bed. A section of the cut shows the following strata:

SECTION No. 695	Ft.	In.
Shale, dark, carbonaceous	3	0
Coal, weathered, **Clarion**	....	10
Clay, flinty, dark, sampled	....	10
Clay, plastic, light, very pure, sampled	2	10
Clay, plastic, light, somewhat siliceous, sampled	4	9
Sandstone light, argillaceous		

The chemical components in the sample of 8 feet 5 inches are as follows.[1] Analyst, Downs Schaaf.

Chemical analysis		Percentage oxide ratio				
Loss at 105° C	1.94	K_2O	.076			
Ignition loss	8.65	Na_2O	.007			
Silica, SiO_2	54.21	CaO	.000	Al_2O_3	1.00	SiO_2 1.927
Alumina, Al_2O_3	28.13	MgO	.020			TiO_2 .071
Ferric oxide, Fe_2O_3	2.29	FeO	.081			P_2O_5 .000
Calcium oxide, CaO	trace					
Magnesium oxide, MgO	0.55	RO	.184			
Titanic oxide, TiO_2	1.98					
Phosphorus pentoxide, P_2O_5	0.01					
Sodium oxide, Na_2O	0.21					
Potassium oxide, K_2O	2.14					
Sulphur, S	0.004					
Total carbon, C	0.17					
Inorganic carbon, C	0.01					

1 Geol. Survey Ohio, 4th Ser., Bull. 31, pp. 212-3, 1927.

Physical tests, by Orton Ceramic Laboratory

Working properties: This clay is smooth and plastic and has a high bonding power. It laminates slightly in auger machines.

Drying behavior: It is easily and safely dried by any of the methods commonly employed.

Drying linear shrinkage—3.7 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	1.5	15.2	Pink buff
Cone 04	4.3	9.2	Light buff
Cone 02	4.3	9.8	Light buff
Cone 1	5.1	8.2	Light buff
Cone 3	5.8	6.2	Buff
Cone 5	5.8	5.4	Buff
Cone 7	6.3	3.0	Gray buff
Cone 9	6.8	1.8	Gray buff
Cone 11	6.8	.2	Gray buff

Overburning temperature: Above cone 11 (above 1,350° C. or 2,462° F.).

Best apparent burning range: Cone 1 to 11 (1,150 to 1,350° C. or 2,102 to 2,462° F.). It is steel hard at cone 1.

Total linear shrinkage at cone 7: 10.0 per cent.

Deformation temperature: Slightly below cone 29 (or slightly below 1,650° C. or 3,002° F.).

Possibilities: Intermediate heat duty refractory ware, face brick, fireproofing, sewer pipe, and terra cotta. This clay burns to a good clear color.

By excluding some of the siliceous clay in the lower part of the deposit, the refractory qualities of the remainder may be increased perceptibly. The deposits are uniform in structure and in character in this locality, are easily accessible, and have good mining conditions.

In its extension eastward the Clarion clay dips rapidly but in King Hollow in Section 3, Brown Township, it may be reached at a depth approximating 90 feet. Much the same conditions also exist along Hewett Fork from Mineral to Carbondale in Waterloo Township, Athens County.

Along Sandy Run northeast of Hope Furnace for a distance of nearly two miles the Clarion clay lies at or only a few feet below the flood plain. This is shown by the frequent appearance of the carbonaceous shale and Clarion coal and even the top layers of clay. At the picnic ground near the southern boundary of Section 11, Brown Township, on land of the Ohio Mineral Company, the Clarion clay appears for a short distance where the stream has eroded the eastern bank to some depth. The clay as thus laid bare

was sampled November 13, 1923, by Wilber Stout assisted by Miles Ogan. Where sampled by channeling the clay was solid and the sample is therefore representative of the material under deep covering. A section here shows the following strata:

SECTIONS NOS. 256, 538

	Ft.	In.
Sandstone, shaly	3	0
Shale, gray	10	0
Coal, somewhat bony, **Scrubgrass**	1	1
Shale, dark, rather fissile	4	3
Shale, hard, bony, blocky	1	8
Coal, blocky, hard, **Clarion**	....	6
Clay, plastic, dark, sampled	....	8
Clay, plastic, light, very pure, sampled	2	8
Clay, plastic, light, siliceous, sampled	2	4
Clay, plastic, light, very siliceous	1	6
Bed of stream	....	....

The sample at this place was thus made up of 5 feet 8 inches of strata which apparently is representative for the region. The chemical components in the clay are given below:[1] Analyst, Downs Schaaf.

Chemical analysis

Loss at 105° C	**0.89**
Ignition loss	**8.02**
Silica, SiO_2	57.73
Alumina, Al_2O_3	27.19
Ferric oxide, Fe_2O_3	1.69
Calcium oxide, CaO	0.08
Magnesium oxide, MgO	0.53
Titanic oxide, TiO_2	1.20
Phosphorus pentoxide, P_2O_5	0.04
Sodium oxide, Na_2O	0.32
Potassium oxide, K_2O	2.44
Sulphur, S	0.23
Total carbon, C	0.16
Inorganic carbon, C	0.00
True specific gravity	2.64

Percentage oxide ratio

K_2O	.090	Al_2O_3	1.00	SiO_2	2.123
Na_2O	.012			TiO_2	.044
CaO	.003			P_2O_5	.001
MgO	.019				
FeO	.062				
RO	.186				

Physical tests, by Orton Ceramic Laboratory

Working properties: This clay is plastic and smooth and works well through the die of the machine without the development of objectionable cracks or laminations.

Drying behavior: The ware dries well in any type of drier.

Drying linear shrinkage: 3.5 per cent.

[1]Geol. Survey Ohio, 4th Ser., Bull. 31, pp. 215-6, 1927.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	1.3	14.05	Light buff
Cone 04	2.0	12.40	Light buff
Cone 02	3.4	10.04	Light buff
Cone 1	3.7	9.38	Light buff
Cone 3	4.0	7.32	Light buff
Cone 5	4.5	7.14	Light buff
Cone 7	5.0	5.46	Light gray buff
Cone 9	5.5	3.64	Light gray buff
Cone 11	5.5	1.61	Gray buff

Overburning temperature: Cone 11 (1,350° C. or 2,462° F.).

Best apparent burning range: Cones 02 to 11 (1,110 to 1,350° C. or 2,030 to 2,462° F.).

Total linear shrinkage at Cone 7: 8.5 per cent.

Deformation temperature: Cone 30 (1,670° C. or 3,038° F.).

Possibilities: Intermediate heat duty refractory ware, face brick, hollow block, fireproofing, and sewer pipe.

In northeastern Brown Township, Vinton County, and in adjacent parts of Athens and Hocking counties, the Clarion clay lies below drainage, hence its intimate characteristics are not known. As determined by the Middle Kittanning coal as a bench of reference, the position of the Clarion clay is close to 90 feet below the valley floors in Section 6, Brown Township, and about the same near Carbondale in Waterloo Township, Athens County. The member is regularly present along Twomile Run in north central Brown Township. In general the bed is slightly below the average in thickness but the material is standard in quality. The structure of the Clarion clay and its relations to beds higher in the Allegheny series are shown in the following composite record taken at the road forks in the northeastern part of Section 23:

SECTIONS NOS. 263 AND 178

		Ft.	In.
Sandstone, soft, massive		75	0
Coal, bony	Middle Kittanning	....	4
Clay with thin coal bands	Middle Kittanning	....	3
Coal, good	Middle Kittanning	2	8
Clay shale	Middle Kittanning	....	1
Coal, good	Middle Kittanning	1	½
Covered		25	8
Coal, weathered, **Lower Kittanning**		....	6
Clay, plastic, light, lower part siliceous, **Lower Kittanning**		9	6
Sandstone, massive, soft		33	0
Shale, gray, siliceous		7	4
Ore, irregular		....	1
Shale, dark, carbonaceous		....	10

Coal, shaly, **Scrubgrass**		....	8
Shale, dark, carbonaceous		3	1
Shale, black, fissile		3	11
Shale, black, fissile, blocky		1	3
Coal, good, **Clarion**		....	10
Clay, light, plastic, excellent	**Clarion**	2	6
Clay, light, plastic, siliceous	**Clarion**	2	6
Sandstone and covered		21	0
Road forks, elevation 785 feet		....	....

In the western part of Section 23 the Clarion clay shows some expansion, locally thickening to as much as 7 feet. It is also up to the standard in quality and retains its usual covering of hard carbonaceous shale. Scattered exposures along Twomile Run in Sections 28 and 29 and along Raccoon Creek in Sections 35 and 36 indicate that the deposits are generally thin and on the average do not exceed 5 feet in thickness. Little change is apparent to the west in Swan Township, Vinton County, and to the north in Washington Township, Hocking County.

In the vicinity of Starr in Starr Township the Clarion member has more normal thickness and properties. This improvement is shown in the following section taken in a wash on the point of a hill in the southwestern part of Section 25, Starr Township, and given below:

SECTION NO. 629

		Ft.	In.
Shale, black, fissile		2	0
Coal, blocky, **Clarion**		....	9
Clay, flinty, dark		....	10
Clay, plastic, light, excellent		2	8
Clay, flinty, light to dark, good	**Clarion**	2	0
Clay, plastic, dark, good		**1**	**2**
Clay, plastic, siliceous, fair		1	4
Sandstone, argillaceous		2	0

The flinty clay, 2 feet in thickness about the middle of the deposit, is only local in distribution. The area offers good conditions for strip mining. Some clay from this farm has been stripped and used by the Logan Clay Products Company of Logan. In the pit controlled by M. J. Cole and located only a short distance from Section No. 629, the clay was sampled by Wilber Stout, September 12, 1939. The section follows:

	Ft.	In.
Shale, weathered	3	0
Coal blossom, **Lower Kittanning**	1	0
Clay, siliceous	2	0
Shale, gray to dark	7	0

Shale, bony, carbonaceous, black		6	0
Coal, blocky, **Clarion**		1	2
Clay, flinty, dark, carbonaceous	....	....	6
Clay, flinty, dark	....	1	0
Clay, light, plastic, fine texture, some slickensides	Sample	1	11
Clay, plastic, dark, soft, good	....	....	7
Clay, light to dark, good, somewhat flinty	....	....	5
Clay, plastic, siliceous		2	6
Floor of pit		....	....

The analyses of the 1 foot 6 inches of the flinty clay at the top and of the 2 feet 11 inches cream clay at the middle portion of the bed are given below: Analyst, Downs Schaaf.

	Top part	Middle part
Silica, SiO_2	48.33	52.47
Alumina, Al_2O_3	29.64	29.83
Ferric oxide, Fe_2O_3*	1.19	0.30
Ferrous oxide, FeO	.....	.....
Pyrite, FeS_2	0.54	0.32
Magnesium oxide, MgO	0.72	0.43
Calcium oxide, CaO	0.05	0.06
Sodium oxide, Na_2O	0.20	0.14
Potassium oxide, K_2O	1.63	1.06
Water, hydroscopic, H_2O—	4.50	2.50
Water, combined, H_2O+	9.79	9.90
Carbon dioxide, CO_2	0.20	0.21
Titanic oxide, TiO_2	2.04	2.10
Zirconium oxide, ZrO_2	<0.01	<0.01
Vanadium oxide, V_2O_3	<0.01	<0.01
Phosphorus pentoxide, P_2O_5	0.15	0.16
Sulphur trioxide, SO_3	0.18	0.09
Manganous oxide, MnO	0.035	0.03
Carbon, organic, C	0.83	0.38
Hydrogen, organic, H	0.07	0.03

*All Fe, other than that allocated to FeS_2, is calculated to Fe_2O_3, since there is too much carbonaceous matter for an accurate FeO determination.

GENERAL CONSIDERATION

The Hope Furnace field of Clarion clay in Brown Township, Vinton County, and in immediate areas in Hocking and Athens counties is thus extensive and well able to support large plants producing heavy outputs of ware. The sections taken throughout the area indicate regional continuity of the bed with no wants and with few places of thin clay. The analyses and tests show that the quality of the clays is uniformly good and in most of the area exceptionally so. It rates as a high heat duty refractory, moderately plastic in character and exceptionally uniform in quality. For comparison the results are combined in the following table.

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TABLE OF ANALYSES—HOPE FURNACE FIELD

	Thickness																			
Flinty clay	Ft.	In.	SiO_2	Al_2O_3	Fe_2O_3	FeO	FeS_2	MgO	CaO	Na_2O	K_2O	H_2O-	H_2O+	CO_2	TiO_2	ZrO_2	V_2O_3	P_2O_5	SO_3	MnO	C	H
Jesse White	2	0	49.72	30.25	1.68	.....	0.42	0.45	0.18	0.15	1.08	1.79	10.50	0.38	2.70	<0.01	<0.01	0.05	0.01	0.04	0.60	0.04
Hope Dam	1	2	45.50	31.06	0.84	.....	0.34	0.75	0.25	0.29	1.47	4.53	10.88	0.40	1.60	<0.01	<0.01	0.20	0.34	0.03	1.34	0.10
M. J. Cole	1	6	48.33	29.64	1.19	.....	0.54	0.72	0.05	0.20	1.63	4.50	9.79	0.20	2.04	<0.01	<0.01	0.15	0.18	0.035	0.83	0.07
Cream plastic clay																						
Jesse White	2	6	44.93	33.80	1.40	.....	0.57	0.68	0.12	0.18	1.15	3.02	11.40	0.36	2.12	<0.01	<0.01	0.10	0.02	0.04	0.20	0.02
Hope Clay Co.	3	0	46.72	33.06	0.68	0.55	0.34	0.19	0.61	0.42	1.53	2.21	11.50	0.02	2.20	<0.01	.....	0.12	0.01	0.01	0.04	.....
Hope Dam	3	5	46.98	32.40	0.53	.....	0.59	0.44	0.40	0.25	1.48	3.20	10.50	0.30	2.40	<0.01	<0.01	0.20	0.03	0.03	0.27	0.02
M. J. Cole	2	11	52.47	29.83	0.30	.....	0.32	0.43	0.06	0.14	1.06	2.50	9.90	0.21	2.10	<0.01	<0.01	0.16	0.09	0.03	0.38	0.03
Siliceous clay																						
Jesse White	2	11	63.22	23.25	0.20	.....	1.01	0.61	0.14	0.28	3.04	1.01	5.72	0.20	1.01	<0.01	<0.01	0.07	0.01	0.04	0.20	0.02
Hope Dam	3	1	64.68	21.60	0.44	0.34	0.28	0.80	0.24	0.48	2.61	1.15	5.70	0.22	1.35	<0.01	<0.01	0.06	0.03	0.03	0.07	.....

Total clay	Loss at 105°C	Ignition loss					Sulphur		Total carbon	Inorganic carbon
A. E. Kennard	1.32	8.69		1.72	.....	.....	0.02	0.017	.....	0.26	0.06
Jesse White	0.92	8.73		1.07	.....	.....	0.05	0.04	.....	0.20	0.00
Hope Hollow-Drayer	1.22	8.02		1.52	.....	.....	0.01	0.006	.....	0.17	0.07
South of Hope Furnace-Drayer	1.94	8.65		1.98	.....	.....	0.01	0.004	.....	0.17	0.01
Ohio Mineral Co.	0.89	8.02		1.20	.....	.....	0.04	0.23	.....	0.16	0.00

CHAPTER III

LINCOLN FURNACE FIELD

GENERAL DESCRIPTION

The second area of importance of Clarion clay, commonly known as the Lincoln Furnace field, is present in southeastern Clinton, southwestern Vinton, and northwestern Wilkesville townships of Vinton County and in northeastern Milton Township of Jackson County. In this field the clay lacks uniformity in thickness and changes in kind from plastic to flint. In Clinton Township the main bodies of clay of ceramic value are confined to Sections 13, 14, 15, 22, 23, 24, 25, 26, 27, and 28. Locally the plastic clays are exceptionally well developed and have high purity and at a few places flint clay in irregular bodies appears alone or with plastic clay. In Vinton Township the Clarion member lies not far above drainage along Pierce Run across the township and along Raccoon Creek from Arbaugh to the southern township line. The clay, however, is patchy in development and variable in kind. The same condition holds true in Wilkesville Township along Raccoon Creek and Rockcamp Run in the vicinity of Hawk. In Milton Township, Jackson County, the clay of most worth is confined to the ridges north of Wainwright in Section 33, and in the vicinity of Lincoln Furnace in Sections 34, 35, and 36. In this part of the field the clay is usually plastic in kind and in places exceptionally well developed.

KINDS OF CLAY

In most of the Lincoln Furnace field the member is made up of plastic clays of the usual kinds, that is, soft flinty clay at the top, cream plastic clay in the middle portion, and siliceous plastic clay at the bottom. The total thickness of the member as thus constituted is from 6 to 9 feet. Locally irregular bodies of flint clay make up part or all of the bed. Stream or current action appears to have aided in the deposition of this material as it shows pronounced cross-bedding and selective separation. In it irregular lenses of flint clay and argillaceous sandstone are interstratified in disorderly arrangement. Either of these materials may predominate in such deposits but in general the clay is the more abundant. The clay is a hard flint, gradating from pure to very siliceous. It is light gray to buff, breaks with a true conchoidal fracture, and

disintegrates into angular fragments on exposure to the weather. The plasticity is low.

ROOF OF CLAY

Throughout this field the roof of the Clarion clay is the Clarion coal, normally developed. It is made up of three benches of coal separated by two partings of impure clay. The thickness of clean coal averages close to 3 feet 7 inches and that of coal and partings 4 feet 3 inches. The coal is an asset of value and may be mined in conjunction with the clay.

The roof of the coal is a hard, dark, fissile carbonaceous shale, the thickness of which varies from 2 to 10 feet. This is overlain by the Vanport limestone, massive in structure and from 5 to 8 feet in thickness. Conditions are thus good for drift mining.

DETAILED GEOLOGY OF LINCOLN FURNACE FIELD

The following section taken from the valley floor to the ridge top along an old furnace road, south of Hamden Furnace in the northeast quarter of Section 28, shows the general geology of the Clarion clay very well.

SECTION No. 468

	Ft.	In.
Shale and covered	10	0
Sandstone, parts covered	46	0
Coal blossom, **Middle Kittanning**	2	0
Clay, light, plastic	1	0
Shale, shaly sandstone, and covered	25	0
Clay, plastic, Clay, flint — **Oak Hill**	3	0
	1	0
Coal blossom, **Lower Kittanning**	1	0
Clay and covered	6	0
Shale and covered	11	0
Limestone, **Vanport**	3	0
Covered	2	0
Coal blossom, **Clarion**	3	0
Clay, light, plastic, **Clarion**	6	0
Sandstone, light, clay-bonded	7	8
Coal, weathered	2	2
Clay, impure — **Winters**	..	3
Coal, weathered	..	5
Clay, plastic, dark	3	6
Shale, gray, siliceous	13	6
Ore, irregular, local	..	6
Shale, gray	7	2
Coal, **Brookville** or **Newland**	..	5
Clay, light, siliceous	1	6
Sandstone, soft, parts covered	43	11
Ore, with shale layers	....	10

			Ft.	In.
Ore, blocky	Upper Mercer (altitude 765 ft.)		....	7
Sandstone, ferruginous			....	5
Ore, soft, siliceous			....	8
Ore, blocky			....	10
Shale, ferruginous			....	6
Sandstone, argillaceous			1	6
Shale and covered			4	0
Coal, bony, **Upper Mercer**			....	4
Clay, siliceous, upper part with coal bands			1	8
Sandstone, soft, massive, parts covered			50	8
Valley floor			....	..

The section shows the relative position of the Clarion clay to the Vanport, Lower Kittanning, Oak Hill, and Middle Kittanning members above and to the Winters, Brookville, and Upper Mercer members below. These units and also the intervals of separation are moderately constant throughout the area. Only a short distance east of the above exposure the Clarion clay was formerly regularly worked by the Puritan Brick Company. The detailed section in the pit follows:[1]

			Ft.	In.
Limestone, **Vanport**			10	0
Shale, black, fissile			1	6
Coal, fair	Clarion		..	9
Shale and bone coal			..	8
Coal, good			1	4
Shale, pyritiferous			..	1½
Coal, good			..	11
Clay, dark, plastic, flinty, sampled	Clarion		1	6
Clay, light, plastic, excellent, sampled			3	6
Clay, light, siliceous, sampled			4	0
Sandstone			2	8

The chemical composition of the sample, 9 feet in thickness, is as follows: Analyst, Downs Schaaf.

Chemical analysis		Percentage oxide ratio			
Loss at 105° C	2.60	K_2O	.054		
Ignition loss	9.33	Na_2O	.007		
Silica, SiO_2	54.33	CaO	.007		
Alumina, Al_2O_3	27.01	MgO	.002	Al_2O_3	1.00
Ferric oxide, Fe_2O_3	2.38	FeO	.079		
Calcium oxide, CaO	0.20	MnO	.000		
Magnesium oxide, MgO	0.05	RO	.149		
Titanic oxide, TiO_2	1.98				
Phosphorus pentoxide, P_2O_5	0.03				
Sodium oxide, Na_2O	0.18				
Potassium oxide, K_2O	1.46				
Manganous oxide, MnO	trace				
Sulphur, S	0.05				
Total carbon, C	0.48				
Inorganic carbon, C	0.03				

SiO_2	2.012		
TiO_2	.073		
P_2O_5	.001		

[1]Geol. Survey Ohio, 4th Ser., Bull. 26, pp. 257-9, 1923.

Mineralogical examination

Quartz abundant, mostly included as silt in clay aggregates. Primary quartz grains also present. Muscovite common in the sand separate as bright cleavage fragments, and plentiful as sericite in the clay separate. Clay substance is a homogeneous aggregate, except for tiny inclusions of iron oxide (limonite) in size about .005 to .01 mm., and for sericite inclusions. Some of the sand grains have so much coating and infiltration of clay that it is not possible to positively identify them. Other minerals present in small amounts in their order of abundance are tourmaline, zircon, biotite (altered), rutile (both free and in quartz), and siderite (sparingly).

Physical tests, by Orton Ceramic Laboratory

Working properties: Good plasticity. Molding properties very good.

Tempering water	23.48 per cent
Drying linear shrinkage	5.96 per cent
Drying volume shrinkage	18.92 per cent

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume shrinkage	Per cent volume absorption	Color
Cone 08	1.69	4.97	25.57	Light cream
Cone 03	3.63	10.50	26.44	Light cream
Cone 2	4.65	13.31	22.53	Cream
Cone 4	5.77	16.34	20.71	Light buff
Cone 6	7.23	20.15	11.78	Medium buff speckled
Cone 9	7.63	21.19	10.19	Medium buff speckled
Cone 12	7.43	20.67	1.91	Gray speckled
Cone 14	7.39	20.57	0.59	Gray brown speckled

Overburning temperature: Above cone 14 (1,410° C. or 2,570° F).

Best apparent burning range: Cones 6 to 14 (1,250° C. to 1,410° C. or 2,282° F. to 2,570° F.).

Total linear shrinkage at Cone 14: 13.35 per cent.

Deformation temperature: Cone 29 (1,650° C. or 3,002° F.).

Possibilities: Intermediate heat duty refractories. If used alone a portion of the clay should be calcined and used as grog to reduce shrinkage.

At the mines, formerly worked by the McArthur Brick Company, on the east side of the hollow in the northwestern part of Section 27, the clay was sampled for chemical testing. The samples were taken October 3, 1939, by Wilber Stout assisted by Henry Sprague. The section is as given below:

	Ft.	In.
Shale, gray	10	0
Ore, irregular, **Ferriferous**	....	10
Limestone, dark gray, massive, **Vanport**	6	10
Shale, black, bony, carbonaceous	1	7
Coal, with thin partings	1	1

		Ft.	In.
Clay and bone coal.....	Clarion	..	4
Coal, good	.....	1	4
Shale with pyrite.....	.....	..	1½
Coal, good	.....	..	11
Clay, dark, somewhat flinty, good quality, some root impressions, sample		1	4
Clay, light, plastic, smooth, fine quality, some slickensides, sample		3	6
Clay, light, siliceous, plastic, not sampled.....		4	0
Sandstone and covered.....		10	0

The chemical composition of the two samples is given below. Analyst, Downs Schaaf.

	Top 1 ft. 4 in.	Cream clay 3 ft. 2 in.
Silica, SiO_2	43.40	47.01
Alumina, Al_2O_3	35.10	33.98
Ferric oxide, Fe_2O_3.....	1.29	1.14
Ferrous oxide, FeO.....	0.12	0.14
Pyrite, FeS_2	0.07	0.09
Magnesium oxide, MgO.....	0.55	0.40
Calcium oxide, CaO.....	0.33	0.29
Sodium oxide, Na_2O.....	0.25	0.22
Potassium oxide, K_2O.....	1.20	1.07
Water, hydroscopic, H_2O—	3.72	2.73
Water, combined, H_2O+	10.10	10.01
Carbon dioxide, CO_2	0.20	0.18
Titanic oxide, TiO_2	2.84	2.27
Zirconium oxide, ZrO_2	<0.01	<0.01
Vanadium oxide, V_2O_3.....	<0.01	<0.01
Phosphorus pentoxide, P_2O_5.....	0.18	0.17
Sulphur trioxide, SO_3.....	0.09	0.11
Manganous oxide, MnO.....	0.02	0.02
Carbon, organic, C.....	0.60	0.32
Hydrogen, organic, H.....	0.04	0.03

Both analyses show clays of excellent purity and high heat resisting qualities. Their deformation range is from cone 31½ to cone 32. Their physical properties are such that they work well for either stiff mud or dry press ceramic ware. In this area the Clarion member appears to be steady in thickness and quality. The associated beds, Clarion coal, Vanport limestone, and Ferriferous ore, are also assets of some value.

Along the ridges in northern Section 21 and in Section 16, Clinton Township, the Clarion clay is present from 880 to 900 feet above tide. Scattered outcrop observations indicate the general thickness of the member is from 5 to 7 feet and the quality fair. At the side of the road in the northeastern part of Section 15 about 5 feet of light to dark plastic clay is exposed at an elevation of 850

feet. Along the road in the east central part of Section 14 the following strata were exposed:

SECTION No. 105

	Ft.	In.
Top of hill, elevation 905 feet	..	..
Covered	8	0
Clay, plastic, **Middle Kittanning**	3	0
Sandstone, light, soft	20	0
Covered	7	5
Sandstone, light, soft	6	0
Shale, coaly	..	5
Coal, good	2	7
Shale, dark — **Lower Kittanning**	..	½
Coal, good	..	6½
Clay, shale, and covered	19	6
Coal, weathered, **Clarion**	2	0
Clay, light, plastic, **Clarion**	5	6
Shale and covered	10	0
Coal blossom, **Winters**	1	0
Clay and covered	6	0
Sandstone, soft	3	0

In the vicinity of Oreton on Pierce Run, Vinton Township, and adjacent parts of Clinton Township, irregular bodies of siliceous, flint clay make up the basal portions of thick deposits lying below the Clarion coal. Stream or current action appears to have aided in the deposition of this material as it shows cross-bedding and selective separation. In it irregular lenses of flint clay and of argillaceous sandstone are inter-stratified in disorderly arrangement, thus producing great local variation. Either of these materials may predominate in such deposits but in general the clay is more abundant. The clay is a hard flint, gradating from quite pure to very siliceous. It is light gray in color, breaks with a true conchoidal fracture, and disintegrates into angular fragments on exposure to the weather. The plasticity is low. The following section shows the relations observed at the mines of the New York Coal Company at Oreton:

	Ft.	In.
Sandstone, shaly	4	0
Shale with ore bands	2	0
Clay, plastic, dark — **Oak Hill**	1	0
Clay, plastic, light — **Oak Hill**	3	8
Sandstone, light, coarse grained	3	4
Shale, dark	1	5
Sandstone, light, coarse grained	3	0
Shale and shaly sandstone, gray	17	0
Coal, good	2	4
Clay shale, dark — **Lower Kittanning**	..	9
Coal, good	..	4

		Ft.	In.
Clay, dark, plastic.....	Lower Kittanning	..	4
Clay, light, plastic.....	Lower Kittanning	6	8
Sandstone, clay bonded, light		20	0
Limestone, **Vanport**		8	0
Shale, dark, varies from 4 to 18 feet		10	0
Coal, good	Clarion	1	2
Clay and bony coal..	Clarion	..	8
Coal, good	Clarion	1	0
Clay with pyrite.....	Clarion	..	1
Coal, good	Clarion	1	2
Clay, plastic, and covered		8	0
Clay, flint, upper part very sandy, sampled		4	0
Shale, argillaceous, light		4	0

The chemical composition of the above flint clay is given below:[1] Analyst, Downs Schaaf.

Chemical analysis

Loss at 105° C	1.38
Ignition loss	9.67
Silica, SiO_2	57.10
Alumina, Al_2O_3	28.17
Ferric oxide, Fe_2O_3	1.81
Calcium oxide, CaO	0.05
Magnesium oxide, MgO	0.12
Titanic oxide, TiO_2	1.44
Phosphorus pentoxide, P_2O_5	0.15
Sodium oxide, Na_2O	0.46
Potassium oxide, K_2O	0.02
Manganous oxide, MnO	0.01
Sulphur, S	0.04
Total carbon, C	0.05
Inorganic carbon, C	0.00

Percentage oxide ratio

K_2O	.001		
Na_2O	.016		
CaO	.002		
MgO	.004	Al_2O_3 1.00	SiO_2 2.027
FeO	.054		TiO_2 .051
MnO	.001		P_2O_5 .005
RO	.078		

Physical tests, by Orton Ceramic Laboratory

Working properties: Short, sandy, difficult to mold.

Tempering water	13.91 per cent
Drying linear shrinkage	1.18 per cent
Drying volume shrinkage	3.59 per cent

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume shrinkage	Per cent volume absorption	Color
Cone 08	1.62	4.78	29.83	Light cream
Cone 03	1.83	5.39	35.28	Light cream
Cone 01	1.64	4.83	34.24	Light cream
Cone 4	2.41	7.07	30.41	Light buff speckled
Cone 7	2.20	6.46	30.20	Light buff speckled
Cone 8	1.89	5.56	32.59	Light buff speckled
Cone 12	1.99	5.85	30.79	Light buff speckled
Cone 14	2.24	6.58	33.62	Light buff speckled
Cone 15	2.45	7.17	32.13	Light buff speckled

[1]Geol. Survey Ohio, 4th Ser., Bull. 31, pp. 217-8, 1927.

Overburning temperature: Above cone 15 (1,430° C. or 2,606° F.).

Best apparent burning range: Cone 8 to above 15 (1,290° C. to 1,430° C. or 2,345° F. to 2,606° F.).

Total linear shrinkage at cone 15: 3.63 per cent.

Deformation temperature: Cone 31 (1,685° C. or 3,065° F.).

Possibilities: High heat duty, siliceous clay refractories. Structure rather weak. A siliceous flint clay showing comparatively slight changes in shrinkage and porosity.

On the property of the Thompson Coal Company near Campbell Tunnel, Section 19, Vinton Township, a sample of flint clay was taken under deep cover in a drift mine working the Clarion coal. The section is given below:[1]

			Ft.	In.
Shale, black			2	0
Coal, fair	Clarion		1	4
Clay with thin coal bands			--	7
Coal, good			1	1
Clay with pyrite			--	1
Coal, good			1	1
Clay, impure			--	6
Coal, poor			--	5½
Clay, plastic, light to dark, sampled	Clarion		1	6
Clay, flint, siliceous, sampled			4	6
Clay, not sampled on account of water				

The results of the tests follow:[2] Analyst, Downs Schaaf.

Chemical analysis		Percentage oxide ratio				
Loss at 105° C.	0.70	K_2O	.030			
Ignition loss	9.11	Na_2O	.014		SiO_2	2.227
Silica, SiO_2	59.54	CaO	.006	Al_2O_3 1.00	TiO_2	.052
Alumina, Al_2O_3	26.74	MgO	.005		P_2O_5	.002
Ferric oxide, Fe_2O_3	1.33	FeO	.050			
Calcium oxide, CaO	0.17	RO	.105			
Magnesium oxide, MgO	0.12					
Titanic oxide, TiO_2	1.40					
Phosphorus pentoxide, P_2O_5	0.06					
Sodium oxide, Na_2O	0.38					
Potassium oxide, K_2O	0.80					
Sulphur, S	0.34					
Total carbon, C	0.14					
Inorganic carbon, C	0.02					
True specific gravity	2.52					

Physical properties, by Orton Ceramic Laboratory

Working properties: The mixture works short owing to the mixture of flint and plastic clay. It has sufficient bonding power, however, to flow through the die without cracks or lamination.

[1]Geol. Survey Ohio, 4th Ser., Bull. 31, p. 208, 1927.

[2]Idem., pp. 219-220.

Drying properties: It dries easily and safely.

Drying linear shrinkage: 2.50 per cent.

Burning behavior

Burning temperature	Per cent linear shrinkage	Per cent volume absorption	Color
Cone 07	1.0	17.17	Light buff
Cone 04	1.7	16.05	Light buff
Cone 02	2.5	13.27	Light buff
Cone 1	2.5	13.27	Light buff
Cone 3	3.0	13.27	Light buff
Cone 5	3.1	13.05	Light buff
Cone 7	3.5	12.30	Medium buff
Cone 9	3.5	12.50	Medium buff
Cone 11	3.5	12.00	Medium buff

Overburning temperature: Above cone 11 (above 1,350° C. or 2,462° F.)

Best apparent burning range: Cones 7 to above 11 (1,270° C. to above 1,350° C. or 2,318° F. to above 2,462° F.)

Total linear shrinkage at cone 11: 6.0 per cent.

Deformation temperature: Cone 31 (1,685° C. or 3,065° F.)

Possibilities: High heat duty refractory ware. It lies just within the limits of this grade of refractory products but will make brick suitable for general purposes.

The analyses show that this flint clay belongs in the siliceous class as it contains about 25 per cent of free silica which component tends to keep the structure open and to counteract the high shrinkage of the clay substance. It is beneficial also in that it aids in resisting the action of acid slags. In this clay the basic fluxes are moderate in amount and common in kind. Locally the stratum contains some diffused pyrite, which is objectionable as it localizes the iron and specks the ware. The heat-resisting qualities of the flint clay on the Clarion horizon, cone 31, place it just within the limit of the high heat duty class but careful selection of material will raise this slightly. The clay is best fitted for the manufacture of general purpose fire brick.

On the farm of John Riley in northeastern Section 25, the Clarion member is exposed at several places along the south bank of the stream. It is made up of both flint and plastic clay, the flint variety occurring as irregular masses in the basal portion of the plastic. The flint clay is of the usual siliceous type but the plastic material is very good. The plastic clay was sampled by Wilber Stout October 3, 1939. The section follows:

		Ft.	In.
Shale, black, fissile		3	0
Coal, good	Clarion	1	5
Clay and bone coal		..	6½
Coal, good		1	3
Clay with pyrite		..	1½
Coal, good		1	2
Coal, very bony		..	3
Clay, dark, somewhat flinty, smooth, with root impressions, sampled		1	1
Clay, light, smooth, uniform, plastic, sampled		4	8
Clay, flint, siliceous, hard, with many irregular sandstone lenses		7	6
Clay, light, plastic, siliceous		1	0
Stream bed		..	..

The chemical components in these samples are as follows. Analyst, Downs Schaaf.

	Flinty clay 1 ft. 1 in.	Plastic clay 4 ft. 8 in.
Silica, SiO_2	54.75	52.53
Alumina, Al_2O_3	27.42	29.30
Ferric oxide, Fe_2O_3	0.68	1.65
Ferrous oxide, FeO	0.20	0.21
Pyrite, FeS_2	0.12	0.14
Magnesium oxide, MgO	0.60	0.59
Calcium oxide, CaO	0.22	0.18
Sodium oxide, Na_2O	0.44	0.46
Potassium oxide, K_2O	2.32	2.45
Water, hydroscopic, H_2O-	2.39	2.05
Water, combined, H_2O+	7.72	8.25
Carbon dioxide, CO_2	0.24	0.18
Titanic oxide, TiO_2	1.95	1.55
Zirconium oxide, ZrO_2	<0.01	<0.01
Vanadium oxide, V_2O_3	<0.01	<0.01
Phosphorus pentoxide, P_2O_5	0.06	0.05
Sulphur trioxide, SO_3	0.03	0.02
Manganous oxide, MnO	0.03	0.02
Carbon, organic, C	0.75	0.35
Hydrogen, organic, H	0.05	0.03

The results of these analyses show both clays to be high grade refractory materials, cone 30 to 31. The plastic clay is well fitted for bonding the flint clay found associated throughout this area.

In Wilkesville Township of Vinton County the Clarion clay is above drainage along Raccoon Creek from Hawk to central Section 20 and along the lower courses of the larger western tributaries, Rockcamp, Indiancamp, and Karr runs. Throughout most of this

area the bed outcrops so near the level of the flood plain that few exposures were found. These, however, indicate that some clay of value is present in this part of the field. The overlying Clarion coal has excellent continuity and good development. Near Hawk in central Section 24, the following strata appear in the cut of the Hocking Valley Railway:[1]

		Ft.	In.
Sandstone, massive		30	0
Shale, bony		..	11
Coal, good	Clarion	1	5
Clay, impure	Clarion	..	7
Coal, good	Clarion	1	2½
Clay with pyrite	Clarion	..	1½
Coal, good	Clarion	1	2
Clay, hard	Clarion	..	2
Coal, bony	Clarion	..	2
Clay, plastic, light to dark	Clarion	1	6
Clay, flint, siliceous, irregular	Clarion	6	6
Clay, plastic, dark, siliceous	Clarion	..	4
Clay, plastic, light	Clarion	2	0
Track level		..	..

The flint clay is light gray in color and fine in texture. Within the stratum are found irregular lenses of very siliceous clay and argillaceous sandstone which, on the whole, constitute but a small part of the mass and which, if objectionable, may be removed in mining.

More than 6 feet of flint clay is exposed at the side of the road in the central part of the southeast quarter of Section 30. It is a hard flint clay fine in texture and siliceous in character. It lies directly below the Clarion coal and 38 feet below the Lower Kittanning coal.

In Milton Township, Jackson County, the Clarion clay is locally well developed in the northern tier of sections. The member passes below drainage on Mulga Run in the western part of Section 36, northeast, at an elevation of 750 feet. Near Lincoln Furnace in Section 35 the Clarion clay is 5 feet or more in thickness and above the average in quality. The following section taken at the mines of the Woodrow Coal and Mining Company in the northeastern part of Section 35 is representative.[2]

	Ft.	In.
Limestone, **Vanport**	7	0
Shale, gray	..	10

[1]Geol. Survey Ohio, 4th Ser., Bull. 31, p. 209, 1927.
[2]Geol. Survey Ohio, 4th Ser., Bull. 26, p. 256, 1923.

		Ft.	In.
Shale, dark, fissile		2	1
Coal, good		1	3
Clay and bone coal		..	8
Coal, good	Clarion	1	1
Shale, pyritiferous		..	1½
Coal, good		1	1
Clay, plastic, light, **Clarion**		5	0

The lower part of the deposit is siliceous but the upper part is a smooth plastic clay of high purity. A large area of Clarion clay is present along the main ridge in Section 34, north, where the member outcrops at an elevation of 830 to 840 feet. The clay varies from 5 to 8 feet in thickness and is of excellent quality. Similar conditions are found in Section 33, north, where the elevation of the bed is from 850 to 860 feet.

GENERAL CONSIDERATION

The Lincoln Furnace field of Vinton and northeastern Jackson counties is not large in comparison with the Hope Furnace field but contains much valuable material available for manufacturing purposes. It contains the normal high aluminous plastic clays and in addition siliceous flint clay of merit. Fuel is present for steam generation and for burning the ware.

TABLE OF ANALYSES—LINCOLN FURNACE FIELD

	Thickness																			
Flinty clay	Ft.	In.	SiO_2	Al_2O_3	Fe_2O_3	FeO	FeS_2	MgO	CaO	Na_2O	K_2O	H_2O-	H_2O+	CO_2	TiO_2	ZrO_2	V_2O_3	P_2O_5	SO_3	MnO	C	H
Puritan Brick Co.	1	4	43.40	35.10	1.29	0.12	0.07	0.55	0.33	0.25	1.20	3.72	10.10	0.20	2.84	<0.01	<0.01	0.18	0.09	0.02	0.60	0.04
John Riley	1	1	54.75	27.42	0.68	0.20	0.12	0.60	0.22	0.44	2.32	2.39	7.72	0.24	1.95	<0.01	<0.01	0.06	0.03	0.03	0.75	0.05
Cream plastic clay																						
Puritan Brick Co.	3	6	47.01	33.98	1.14	0.14	0.09	0.40	0.29	0.22	1.07	2.73	10.01	0.18	2.27	<0.01	<0.01	0.17	0.11	0.02	0.32	0.03
John Riley	4	8	52.53	29.30	1.65	0.21	0.14	0.59	0.18	0.46	2.45	2.05	8.25	0.18	1.55	<0.01	<0.01	0.05	0.02	0.02	0.35	0.03
Total clay												Loss at 105°C	Ignition loss						Sulphur		Total carbon	Inorganic carbon
Puritan Brick Co.	9	0	54.33	27.01	2.38	.....	.....	0.05	0.20	0.18	1.46	2.60	9.33	.....	1.98	.....	.....	0.03	0.05	trace	0.48	0.03
New York Coal Co.....	4	0	57.10	28.17	1.81	.....	.....	0.12	0.05	0.46	0.02	1.38	9.67	.....	1.44	.....	.....	0.15	0.04	0.01	0.05	0.00
Thompson Coal Co.....	6	0	59.54	26.74	1.33	.....	.....	0.12	0.17	0.38	0.80	0.70	9.11	.....	1.40	.....	.....	0.06	0.34	.....	0.14	0.02

CHAPTER IV

ECONOMIC VALUE OF CLARION CLAY

As revealed to the eye, the Clarion clay of the Hope and Lincoln Furnace fields is exceptionally pure for a material refined by nature through transportation and sedimentation. It has the texture and appearance of high grade clay, varying from a hard plastic to a semi-flint in character. The clay throughout the fields is practically devoid of large concretions of ferruginous matter and contains few oolites of similar composition. Pyrite, common to nearly all sedimentary clays, is locally present. The quantity is small and for all ordinary purposes the amount present is not damaging. The pyrite may occur in scattered grains, in small concretionary masses, and in thin platy particles. Gypsum or anhydrite crystals are uncommon except along the outcrop where the clay has been penetrated by plant roots. In the siliceous clay in the basal portion of the member sericitic mica is present in bright scales of small size. The appearance, hardness, and composition of the normal clay of the Clarion member justifies a classification about midway between a typical plastic clay and a true semi-flint clay.

Both the analyses and the physical and fire tests of the Clarion clay in the Hope and Lincoln Furnace fields give it a high rating for a plastic material, in fact, one of the best in the United States. An outstanding feature of importance is the uniformity in composition throughout wide areas of the fields, thus guaranteeing constancy of product. In the cream and flint clays the free silica is low, around 10 per cent, the alumina high, from 29 to 34 per cent, and the total bases moderate, from 3 to 4.5 per cent. All the components are thus well within the limits of high grade refractory clay.

The plastic properties of the normal Clarion clay are not high but the bonding strength is all that is necessary for ease in working through machines and dies. The column is smooth and has few defects, such as cracks and laminations. The green ware dries safely in any of the common types of driers now in commercial use. Both the drying and the fire shrinkage are low to moderate. The physical properties of the Clarion clay, moderate plasticity and grainy texture, fit it especially for dry press work. The powdered

material, under the action of the press, compacts firmly and densely without shearing.

The Clarion clay has a long burning range, averaging ten cones or more. The burned ware becomes steel hard at cone 3 to cone 5 and reaches good maturity at cone 8 to cone 15. The ware is relatively free from warping, dishing, and checking defects and also from blisters, pimples, and scums. The body burns to a good clear buff color with good finish and appearance.

The Clarion clay in the Hope and Lincoln Furnace fields is especially fitted for stiff-mud and dry-press fire brick for intermediate and high heat duty service. Such ware is easily made by either process. The cream clay lends itself to the production of light weight, porous, insulating ware, now useful in many fields of industry. The structure of the brick is good and the insulating power high. Tests also show the Clarion clay, from the full thickness of the member, to be adaptable for the manufacture of terra cotta, sewer pipe, fireproofing, building brick, and other heavy clay products. The fields of Clarion clay are large, have satisfactory labor near by, are supplied with fuel and electrical power, and are adjacent to lines of transportation. They are assets of real value.